How energy efficiency programs influence energy use: an application of the theory of planned behaviour

David Lynch
Centre for Regional Innovation and Competitiveness
University of Ballarat
PO Box 691
Ballarat VIC 3353
Australia
d.lynch@ballarat.edu.au

Peter Martin
Centre for Informatics and Applied Optimization
University of Ballarat
PO Box 663
Ballarat VIC 3353
Australia
p.martin@ballarat.edu.au

Keywords
energy efficiency programmes, impact evaluation, quasi-experimental design, theory of planned behaviour

Abstract
During the 2007 Australian Federal Election, opposition leader, Kevin Rudd, declared climate change to be "the great moral challenge of our generation". This claim reflected political and social sentiment recognising climate change and energy efficiency as national priorities. Despite this realisation, implementing energy policy and complementary energy efficiency programs have been problematic. This study examined how energy efficiency programs influence participant behaviour in the context of the Central Victoria Solar City (CVSC) program. CVSC was designed to increase participant energy efficiency, and decrease reliance on non-renewable energy sources. The study used a non-equivalent groups design, which involved analysing electricity and survey data from a sub-sample of 542 matched intervention and control group participants. The results indicate that 5.8 % of electricity use reductions in the intervention group can be attributed to the CVSC program. The study found the Theory of Planned Behaviour (TPB) is a plausible model to explain household energy use intentions and behaviour. Intentions to reduce energy use were influenced by environmental and financial attitudes towards reducing consumption and perceived control over such behaviour. This finding suggests that programs that successfully influence participant attitudes towards energy conservation and address barriers to adopting such behaviours are likely to have a positive effect on reducing energy use. The authors propose that changes in intentions and behaviour may be driven by programs fostering more favourable attitudes and beliefs towards energy use rather than by strengthening the relationships between the TPB constructs. This study's approach contributes to the emerging body of knowledge on suitable methods for evaluating the impact of energy efficiency programs and policies, and understanding their influence on participant attitudes and beliefs.

Introduction
Peter Drucker succinctly defined efficiency as "doing things right". Encouraging households and industry to *do the right thing* about energy use has been a major challenge for policy makers responsible for ensuring energy security and lowering carbon pollution. It is therefore paramount that energy efficiency policies are based on reliable research about not only what policies work, but extends to how they work and under what conditions.

The rationale for government intervention to encourage investment in energy efficiency is based on the notion of market failure. Such free market inefficiencies have been described as the *energy efficiency gap*, which is the difference between optimal and actual levels of investment in energy efficiency (Jaffe & Stavins, 1994). Proponents of the energy efficiency gap suggest that market failure and barriers are major contributors to this underinvestment in energy efficiency (Dietz, 2010). Market failures identified include: energy pricing not reflecting social costs (e.g. pollution, CO_2 emissions) and consumers lacking information and cost incentives to invest in energy efficiency. Identified market barriers include: uncertainty about future energy prices and energy efficient investment (e.g. higher discount rates); hidden costs (e.g. adoption, search, maintenance, training) and energy efficiency investments being effective for some but not others (i.e. varied outcomes).

A central economic question around energy efficiency is: can government intervention correct investment inefficiencies? Policy measures designed to address such inefficiencies include: a Pigouvian tax to create an incentive to use more environmentally friendly methods of production; a cap and trade system (e.g. ETS) that allows trading of emissions allowances; energy efficiency subsidies and standards; and energy efficiency programs designed to foster sustainable behaviour and accelerate adoption of energy efficient technologies (i.e. market transformation). Although such measures are well recognised, a lack of credible empirical research makes it difficult to assess the extent of the energy efficiency gap and the potential influence of both independent and complementary government policy measures (Allcott & Greenstone, 2012).

AUSTRALIAN ENERGY POLICY CONTEXT

A review of Australian energy policies – the site of this study – by the International Energy Agency identified environmental sustainability as our greatest challenge (IEA, 2005). This sentiment was endorsed by Opposition Leader (and soon to be Prime Minister), Kevin Rudd, who declared climate change to be "the great moral challenge of our generation" during the 2007 Australian Federal Election. During this period, it was suggested that energy efficiency can increase the Australian economy's GDP and employment and the energy sector would benefit from greater government efforts to improve energy efficiency throughout the economy (Energy Task Force, 2004; IEA, 2005). In response to such recommendations, and scientific evidence suggesting that Australians are exposed to damaging risks associated with climate change, a comprehensive review of the impacts of climate change was undertaken (known as *The Garnaut Review*). This review examined how Australia was likely to be affected by climate change and how government policy could best contribute to climate change mitigation, and adaptation. Garnaut (2008) suggested there were two basic approaches to achieving the required emissions reduction: a market-based approach, built around putting a price on carbon emissions; and a regulatory approach, or direct action. Garnaut (2008) recommended a three-year fixed carbon price followed by a carbon trading scheme with a floating price. The Australian Government adopted this approach, with a carbon price introduced in July 2012.

Although introducing a carbon tax is the major feature of Australia's energy efficiency and climate change mitigation policy, this is not viewed as a panacea for securing energy supply, enhancing Australia's economic growth potential and lowering carbon pollution. Thus, complementary actions to overcome market failures and non-price barriers have been identified in the Australian Government's Energy Policy Framework. A major objective of this framework is to empower consumers directly to manage their energy use efficiently and effectively (DRET, 2012). This objective includes two major elements: fostering adoption of energy efficiency technologies and services; and providing consumers with information to support decision-making and enable behavioural change (DRET, 2012). A key issue for achieving these objectives is to develop a better understanding of the drivers of change in energy use (and productivity), which in turn can support more informed policy decisions.

SOLAR CITIES PROGRAM

The Australian Government's Solar Cities program is an example of a research trial designed to gain a better understanding of consumer response to the adoption of energy efficiency technologies and services. The program was carried out in seven separate regions across Australia, including Central Victoria. Central Victoria Solar City (CVSC) encourages central Victorian residents to test the effectiveness of different energy efficiency and renewable energy products and services in reducing energy use and reliance on non-renewable energy. CVSC is funded by the Australian Government through the Department of the Climate Change and Energy Efficiency, Sustainability Victoria, the Sustainability Fund and the Central Victoria Solar City Consortium. Managed by Sustainable Regional Australia, CVSC's consortium members include Bendigo and Adelaide Bank, Central Victorian Greenhouse Alliance (CVGA), Origin and Powercor.

The CVSC program involved recruiting 1,873 household research participants (intervention group) and a control group of 715. The research trial involved recording changes to their energy consumption for up to five years. Each household in the intervention group received a free walkthrough Home Energy Assessment (HEA) to identify areas of energy waste or inefficiency. Following the assessment, participants were provided with a series of recommendations to improve their energy efficiency and were given the opportunity to take part in one or more of the program's other packages. These extra packages were: retrofit package (AUD$500/€400 rebate on AUD$2,000+/€1,600+ energy efficiency investments); solar hot water; household solar photovoltaic system (1.5 kW); and in-home energy displays (IHDs).

PURPOSE OF THE STUDY

This study attempts to explain how the CVSC program has influenced household energy use and the major psychological drivers of electricity consumption. It does this by applying the Theory of Planned Behaviour (TPB Ajzen, 1991) to explain electricity use intentions and behaviour and assessing the program's influence on strengthening relationships between the model's constructs. Although extensive research has tried to explain the characteristics and dynamics of energy use and pro-environmental behaviour (e.g. Abrahamse & Steg, 2009; Olli et al., 2001; Stern et al., 1999) and the impact of energy efficiency programs (e.g. Geller, 2002; Macintosh & Wilkinson, 2011; Steg et al., 2006), there has been little research on *how* such programs influence energy behaviour.

In this context, the purpose of this research is to fill this gap in the literature by using a quasi-experimental design to examine how energy efficiency programs influence participant behaviour. Factors within the TPB were used as measures of attitudes and beliefs, and as a model to explain energy use intentions and behaviour. Specifically, this research has three objectives:

1. To examine changes in electricity use attributable to the program.
2. To test how attitudes and beliefs influence participant intentions to reduce energy use and actual behavioural changes.

3. To test if program participation strengthens the influence of attitudes and beliefs on intentions to reduce energy use and actual behavioural changes.

The rest of the article is structured as follows: First, a review of the literature summarising previous research on household energy conservation and the study's theoretical framework is presented. Next, the procedures used to collect and analyse the study's data are described. The results from the data analysis are then presented. The article ends with a discussion of the study's findings and research contributions and directions for future research.

Literature Review

The following section details the linkages between existing knowledge in the energy behaviour field and this study.

HOUSEHOLD ENERGY CONSERVATION

Household energy conservation efforts can be divided into two categories: curtailment and efficiency behaviour. Curtailment behaviours are everyday actions that help to conserve energy (e.g. turning off lights, lowering thermostat settings). Efficiency behaviours are one-off installations of devices that enable ongoing energy conservation (e.g. buying efficient appliances, installing insulation). The energy-saving potential of efficiency behaviour has been found to be greater than that of curtailment behaviour (e.g. Stern, 2002). For instance, households may save more energy by installing more efficient appliances than by minimising the use of inefficient devices. A contradiction may arise, however, if people use efficient appliances more often than they otherwise would have because they are cheaper to operate (i.e. the rebound effect or Jevons Paradox). Such situations highlight the need to consider the relationship between adoption of energy technologies and knowledge of how to use them efficiently, when evaluating the influence of conservation efforts on household energy consumption.

BEHAVIOURAL PERSPECTIVE

Existing studies on household energy behaviour are typically based on interdisciplinary ideas from economics, psychology and sociology. The primary purpose of such studies has been to stimulate behaviours that are more energy efficient and/or will reduce energy-consuming behaviours. Despite the prevalence of research addressing such issues, understanding energy behaviour still presents many complexities. Such issues include difficulties in identifying and measuring the factors that influence energy-consumption and the nature of each influence on behaviour. Stern (1992) suggests potential factors include psychological, social structures, economic, technological and other variables. Similarly, Abrahamse et al. (2005) propose that energy consumption is a complex interaction between macro-level factors (e.g. technological, economic, demographic and institutional factors) and an individual's motivational factors (e.g. preferences, attitudes), abilities and opportunities.

Barr et al. (2001) sought to provide a broader understanding of environmental behaviour, through a framework that suggests consumption is mainly influenced by social and environmental values, situational variables and psychological factors. The link between values and conservation behaviour builds on previous studies, which have found that social values are associated with environmental practices (Corraliza & Berrenguer, 2000; Stern et al., 1995). A wide range of social science studies have also examined the influence of environmental values on behaviour. In general, such studies have failed to provide conclusive evidence that support the effect of values on behaviour (e.g. Steel, 1996; Vining & Ebreo, 1992). A possible reason for the failure to identify such a relationship could be attributed to the moderating and mediating effects of situational variables (e.g. physical infrastructure, geographical location, socio-economic structure and knowledge) or psychological variables (e.g. attitudes, social norms), which have received considerable attention in the past forty years (Azjen & Fishbein, 1980; Stern et al., 1992).

Despite the prevalence of literature into the determinants of energy consumption, such factors are rarely considered when evaluating the effectiveness of energy programs. Indeed, Abrahamse et al. (2005) found that only 25 % of studies reviewed controlled for behavioural determinants. Such omissions inhibit the ability of these evaluations to examine if the differences observed in post-program energy consumption are caused by the intervention itself or by something else (i.e. counterfactual explanations). This study seeks to consider such confounding effects by comparing the influence of the CVSC program in the context of psychological determinants of energy use, specifically by applying the Theory of Planned Behaviour to explain participant intentions and energy consumption changes.

THEORY OF PLANNED BEHAVIOUR

Many models of consumer behaviour have been proposed in the literature (e.g. Howard & Sheth, 1969; Engel et al., 1990; Peter & Olson, 2004). However, because of its parsimonious explanation of consumer behaviour and its currency in the marketing, psychology and energy efficiency literature, Ajzen's (1991) TPB was used by this study as a framework for explaining the influence of CVSC program participation on behaviour. The following provides an overview of this attitude-behaviour model.

The TPB proposes that a person's behaviour is a direct function of their intentions, which mediates the influence of attitudes, subjective norms and perceived behavioural control (refer Figure 1). The theory is an extension of a previous model known as the theory of reasoned action, which does not include the perceived behavioural control construct (Ajzen & Fishbein, 1980).

The TPB asserts that an individual's given behaviour is predicted by their intention to perform that behaviour. When an individual's behaviour is intentional, then the TPB suggests that these intentions can be predicted by three primary antecedents: attitudes towards the behaviour, subjective norm and their degree of perceived behavioural control. Attitude towards the behaviour is a personal variable reflecting a psychological tendency, or feeling, expressed by an individual towards a behaviour, either favourably or unfavourably. A social norm is a socially oriented variable and represents a person's beliefs about a behaviour, based on perceptions of how other influential persons believe they should behave and their motivation to comply with such beliefs. Perceived behavioural control is an externally oriented variable and reflects how easy or difficult an individual believes it is to perform the behaviour.

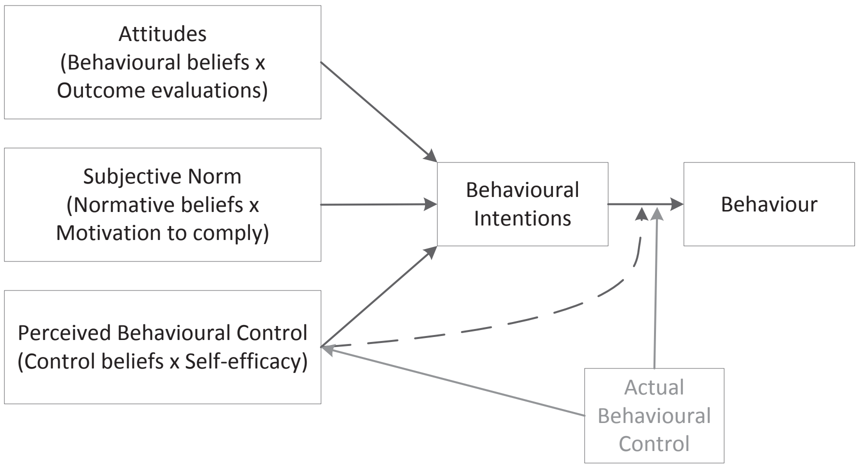

Figure 1. Theory of Planned Behaviour (Ajzen, 2005).

Although the TPB has been criticised for various reasons, such as a focus on rational decision making, rather than emotions (e.g., Ajzen & Fishbein, 2005), it has been widely used in dozens of peer reviewed studies, and has a rich history of use in behaviour change for social causes. For example, the framework has been used to predict energy use (Abrahamse & Steg, 2011; Harland et al., 1999) and conservation technology adoption decisions (Lynne et al., 1995). Various meta-analysis studies have shown the TPB to be a robust and useful tool for predicting behaviours in a wide range of situations (e.g., Armitage & Conner, 2001). Although such studies have tested how well the TPB explains intentions and behaviour, none of the extant literature has assessed if energy efficiency program participation strengthens the influence of each of the models constructs on energy use intentions and behaviour within an experimental or quasi-experimental setting.

Methodology

The following section describes the study's research design and procedures used to carry out the study.

EVALUATION DESIGN

The voluntary nature of participation in energy efficiency programs often means that a true experimental design (i.e. randomised controlled trial) with randomly assigned treatment (i.e. intervention group) and non-treatment (i.e. control group) groups is not possible. As intervention groups for the CVSC program are self-selected, a non-equivalent groups quasi-experimental design (NEGD) was adopted for this study. The Non-Equivalent Groups Design (NEGD) is probably the most frequently used design in social research (Trochim, 2001). A NEGD arises when program participants volunteer for different interventions, rather than through random assignment. This is the case with the CVSC evaluation, where intervention (self-selected) and control group (randomly selected) participants were not equivalent in the way they were recruited to take part in the study. A simple pre-post design without a control group, would not allow for testing of whether differences would have occurred without the intervention. Therefore, this study has used a pre-post design with matched control groups to enable measurement of changes in electricity use attributable to the CVSC program. For interested readers, a more comprehensive review of the NEGD can be found in Cook & Campbell (1979).

DATA COLLECTION

A longitudinal design was employed, with measurements at baseline (and before baseline for some measures, e.g. historical energy consumption, climate data) and at intervals throughout the remainder of the CVSC program. Data collection began in 2010, and will continue until the program's conclusion in June 2013[1]. Three major data sources were collected and monitored for this study: electricity use, participant surveys and climate data.

ELECTRICITY USE DATA

For evaluation purposes half-hourly energy use data was collected from all participating households. This interval meter data is collected by the region's electricity distributor (Powercor) from all households in the program's intervention and control groups. Information about pre-program quarterly electricity use was also provided retrospectively, for up to three years. Data on energy use from reticulated gas or other sources was collected by means of self-reporting of household bills.

PARTICIPANT INFORMATION

To collect information about the determinants of energy consumption, baseline surveys were conducted with all participating households as part of the sign-up process. Follow-up surveys were also conducted on two further occasions following completion of program interventions.

The baseline surveys involved distributing two separate questionnaires to participating households. Each survey was administered using Dillman's *Total Research Design* method (Dillman, 2007). The first survey was a self-administered mail survey distributed to participants after expressing an interest to take part in the study. This initial survey mainly focused on household characteristics such as site details, appliances, lighting, energy bills, reticulated gas and other energy sources and

1. The data used for this study was collected up to June 2012.

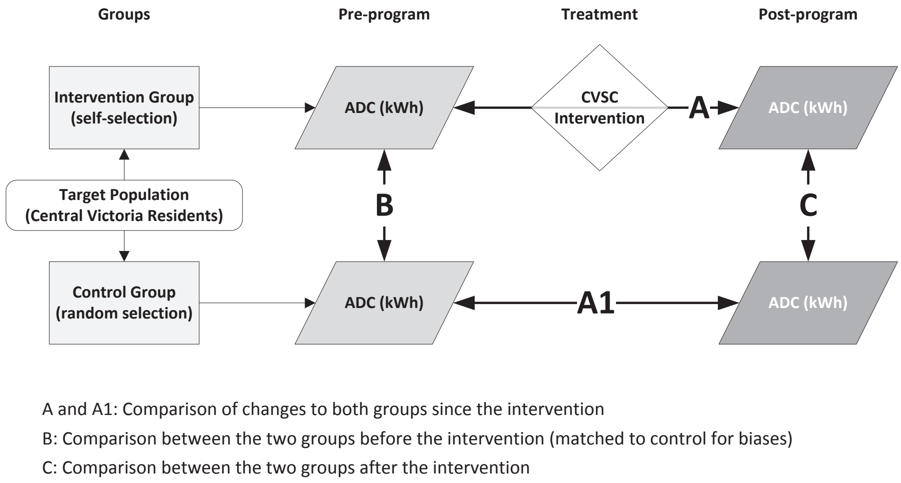

Figure 2. Evaluation Design.

energy efficiency measures. On submission of the first survey booklet, participants were provided with a second questionnaire in the form of a mail, web or a telephone survey, depending on the respondent's preference. This second survey collected information about environmental values, knowledge, views and opinions on energy use, information sources and demographic characteristics. In total, 1,873 intervention group and 715 control group participants fulfilled these initial survey requirements.

Follow-up surveys included a review of demographic characteristics, building characteristics, appliances, psychological characteristics, retrospective information on use of reticulated gas and other energy sources; and questions specific to particular interventions. These questions addressed issues of satisfaction, value, changes to housing and demographic characteristics, attitudes towards solar energy technologies, free-ridership and spill-overs, and other suitable items.

CLIMATE DATA

Local climate data was sourced from the 14 Local Government Areas involved in the program. Relevant climate covariates included meteorological measures such as heating degree days, cooling degree days, temperature, wind speed, cloud cover, rainfall and relative humidity.

MISSING DATA

Missing value analysis was applied to explore the prevalence and nature of missing data from participant survey. This process found the frequency of missing data was small (ranging from <1 % to 5 %). The item with the highest proportion of missing values was income, which is a common issue in survey research.

To assess the nature of the missing data, Little's MCAR Test was applied to each of the items with incomplete data separately for attitudinal items and participant characteristics. The significant test values for attitude measures (Little's MCAR Test: χ^2=1,915, df=1,305, $p<0.05$) and housing/socio-demographic characteristics (Little's MCAR Test: χ^2=4,895, df=2,924, $p<0.05$) indicate that the missing data on these items was related to the pattern of missing values in one or more related variables. Due to this departure from randomness of the missing data, these items cannot be considered Missing Completely at Random (MCAR). As several common methods for treating missing data (e.g. listwise, pairwise, regression) require missing values that are MCAR it was not possible to apply such techniques to items which violate this assumption. To overcome this limitation, an Expectation Maximisation (EM) method was applied, which only requires an assumption of missing at random (MAR) (Little & Rubin, 2002).

MEASUREMENT

Measures for constructs of TPB variables were taken from the TPB Manual (Francis et al., 2004). The measures of attitudes, subjective norm, perceived behavioural control and behavioural intentions were presented to respondents as statements anchored by Likert scales from 1 (strongly disagree) to 5 (strongly agree). Participant behaviour was measured using electricity meter data. The items used to measure each construct are presented in Table 1.

Confirmatory factor analysis (CFA) was undertaken to assess the convergent and discriminant validity, and reliability of these measures. Because the observed indicators were measured using ordinal Likert scales, the use of product-moment correlations are not appropriate (Jöreskog, 1990). Therefore, polychoric correlations were calculated and CFA was undertaken using a Weighted Least Squares (WLS) estimation method. The results from this analysis suggested that the hypothesised TBP model did not have a good fit with the data (CFI=0.97, RMSEA=0.115). Analysis of the reliability for each construct suggested that the two indicators for attitudes: outcome evaluation was low (ρ=0.45), while reliability for the model's other constructs was high (>0.70). This finding suggests that outcome evaluations relating to environmental and financial benefits of reducing energy use are not a unidimensional construct. This interpretation was confirmed when removing the outcome evaluation measures from the model resulted in an excellent fit with the data (CFI>0.99, RMSEA=0.05).

Following the CFA, composite scores were computed for each of the TPB variables to consider the measurement error of each indicator. As the unidimensionality of outcome evalu-

Table 1. Measurement items and reliability.

Construct	Items	Raykov's ρ
Attitudes: behavioural beliefs	• Using less energy will save my household money • Using less energy will reduce my household's impact on the environment	0.76
Attitudes: outcome evaluation	• Reducing my household's energy bill will improve my financial situation • Reducing my household's impact on the environment would be a good thing	0.45
Subjective norm: normative beliefs	• Most people whose opinions I value would approve if I used less energy • Most people whose opinions I value would approve if I installed energy saving devices	0.91
Subjective norm: motivation to comply	• Generally speaking, I care greatly what important people in my life think I should do	N/A
PBC: Control beliefs	• The decision to use less energy in my household is beyond my control • The decision to install energy saving devices in my household is beyond my control	0.83
PBC: Self-efficacy	• It is too difficult for my household to use energy in a better way	N/A
Behavioural intentions	• I plan to use less energy in my household over the next twelve months • I plan to install energy saving devices in my home over the next twelve months	0.76

Note: To reduce participant burden, single-item measures of motivation to comply and self-efficacy were used. Ajzen (2005) suggests that such single-item measures have "proved quite adequate for the assessment of particular attitudes or personality traits" (p. 8).

ations was not confirmed by the analysis, separate attitudinal composites were calculated for financial and environmental attitudes. Each composite score was proportionally weighted by each indicator's regression coefficient to preserve the original scale of the data and therefore aid analysis interpretation.

MATCHED PAIRS

A problem created by quasi-experimental research designs is that there may be systematic differences between the intervention and control groups besides intervention exposure (Stuart, 2010). In such cases, any observed differences between the groups for variables of interest (e.g. electricity use, behavioural intentions) might be due to confounding variables (e.g. climate, gas connection, demographic characteristics) rather than the intervention itself. Therefore, there is a need to control for such potential biases through sampling and statistical adjustment.

To increase comparability between the evaluation's intervention and control groups a matched pairs design was used. This process involved propensity score (the probability of receiving the intervention based on measured covariates) matching of intervention participants with control group households based on a composite of background variables and pre-program adoption of renewable energy technologies (i.e. Household Solar Electricity and Solar Hot Water). For the current study, this process was limited to participants whose energy use data was available for 12 months pre and post the program's intervention period (Intervention Group n=372; Control Group n=362). After estimation of the propensity score, a 'greedy' matching procedure (1:1) was used to match intervention and control group participants. Following this procedure, the matched sample included 542 participants split evenly between the intervention and control groups.

Data Analysis and Results

The following summarises data collected from the study and reports results of inferential statistical analyses. The purpose of these analyses was to explain how the CVSC program has influenced household energy use and the major psychological drivers of electricity consumption.

DESCRIPTIVE STATISTICS

As shown in Table 2, there are strong similarities between the matched control and intervention groups on socio-demographic and property characteristics. The only difference of significance was for gas hot water services, which were more prevalent in the control group (46 % vs. 33 %).

Table 3 summarises participant characteristics associated with the psychological and behavioural factors aligned with the TPB. Both Intervention and Control groups exhibited skewness for average daily consumption (ADC), which necessitated the use of log transformations. The only significant difference noted for the TPB variables was for *intentions,* which is not surprising considering the self-selected intervention group had made some level of commitment to reduce energy use by deciding to take part in the program. While both financial and environmental attitudes and perceived behavioural control were high for both groups, subjective norms were relatively low.

Electricity Use

For time series data such as this it is often helpful to smooth the data to make any trends in the data more apparent. In this case 4-point moving averages were selected to remove the obvious seasonal effects (refer Figure 3). The moving average shows the downward trend in energy use for both the intervention and control groups before and after the treatment period (first half of 2011).

Table 2. Socio-demographic and property characteristics (%).

	Group	
Characteristic	Intervention (n=271)	Control (n=271)
Age		
18–34yo	5%	6%
35–44yo	14%	13%
45–55yo	28%	25%
55–64yo	30%	32%
65+yo	23%	25%
Income		
$50,000 or less (€40,000 or less)	44%	47%
$50,001–$100,000 (€40,001–€80,000)	35%	37%
$100,001 or more (€80,001 or more)	21%	16%
Education		
Secondary School	30%	35%
TAFE (vocational)	15%	15%
Tertiary	55%	49%
Employment Status		
Employed	63%	58%
Not employed	1%	2%
House Duties / Volunteer Work	6%	6%
Retired	30%	34%
Gas Connection		
Reticulated gas	45%	52%
Bottled gas	28%	23%
No connection	27%	25%
House Size		
Small	31%	31%
Medium	54%	55%
Large	15%	14%
Hot Water Type		
Electric	45%	39%
Gas*	33%	46%
Solar	19%	14%
Other	3%	2%
Solar PV (% with)	15%	13%
Property Tenure		
Owned	57%	58%
Mortgage	42%	41%
Rent	1%	0.4%

** p<0.05*

CHANGE IN ELECTRICITY USE

A repeated measures ANOVA (rANOVA) was conducted to assess whether there were differences in changes to energy use between the intervention and control groups. Due to observed non-normality for the energy use measures, this analysis was undertaken on log transformations. The analysis indicates that there was no significant difference between the two groups' pre-intervention energy use ($F(1)=0.53$, $p>.05$). The results do suggest that changes in energy use were significantly affected by participation in the CVSC program (Wilks' Lambda=0.943, $F(1, 540)=32.42$, $p<.05$). This finding suggests that program participants, on average, achieved a greater reduction in electricity use than the control group (refer Figure 4).

To obtain a measure of effect, the relative difference between the post-intervention and pre-intervention data was determined (ADC in 2011–12 financial year and 2010). The change measure used represents the change in the log of the energy use (CLEU). The CLEU measure is a ratio of ratios (the change in the intervention group relative to the change in the control group) or in logarithmic terms a difference of differences (the difference between the changes in intervention and control groups). This analysis found that the overall reduction in energy use for the intervention group was 5.8 % more than that for the control group.

EXPLAINING ENERGY USE INTENTIONS AND BEHAVIOUR

A path analysis was used to test the fit between the TPB model and the data collected for the study. The combination of TPB variables provided a plausible explanation of behavioural intentions and behaviour (changes in electricity use) ($\chi^2(3) = 8.5$, $p > 0.01$; CFI = .98; NFI = .98; RMSEA = 0.06). The regression weights, presented in Table 4, suggest that attitudes (environ-

Table 3. Participant characteristics: TPB variables and electricity use.

	Intervention group			Control group			
	Mean (SD)	Median	Skew	Mean (SD)	Median	Skew	Scale
TPB							
Intentions*	4.1 (0.56)	4.0	-0.21	3.7 (0.78)	3.6	-0.46	1-5
Attitudes (financial)[1]	16.6 (5.35)	16.0	-0.06	16.9 (5.68)	16.0	-0.07	1-25
Attitudes (environmental)[2]	19.6 (4.45)	20.0	-0.10	19.4 (5.12)	20.0	-0.47	1-25
Subjective norm[3]	12.3 (4.44)	12.0	0.05	12.5 (4.93)	12.0	0.30	1-25
PBC[4]	16.6 (4.91)	16.0	-0.06	15.9 (5.08)	16.0	-0.16	1-25
Electricity Use							
ADC kWh (2010)	19.9 (12.67)	17.2	1.23	18.3 (10.93)	15.9	1.87	kWh
ADC kWh (2011/12)	15.6 (9.75)	13.3	1.28	16.7 (9.91)	14.2	1.51	kWh
Log ADC kWh (2010)	1.2 (0.29)	1.2	-0.24	1.2 (0.24)	1.2	0.03	log(kWh)
Log ADC kWh (2011/12)*	1.1 (0.28)	1.1	-0.19	1.2 (0.25)	1.2	-0.03	log(kWh)

$p<0.05$

[1] Product of financial belief strength (fb) and financial outcome evaluation (fo): $Attitudes\_financial_i \propto \sum fb_i fo_i$

[2] Product of environmental belief strength (eb) and environmental outcome evaluation (eo): $Attitudes\_environmental_i \propto \sum eb_i eo_i$

[3] Product of normative belief (n) and motivation to comply (m): $SN_i \propto \sum n_i m_i$

[4] Product of control belief (c) and self-efficacy (s): $PBC \propto \sum c_i s_i$

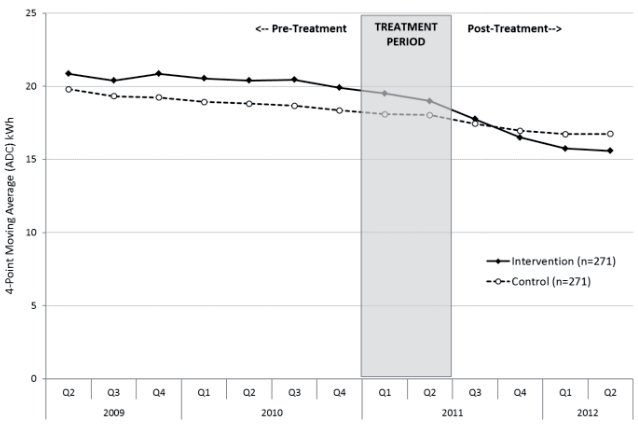

Figure 3. Average Daily Consumption (kWh) by group.

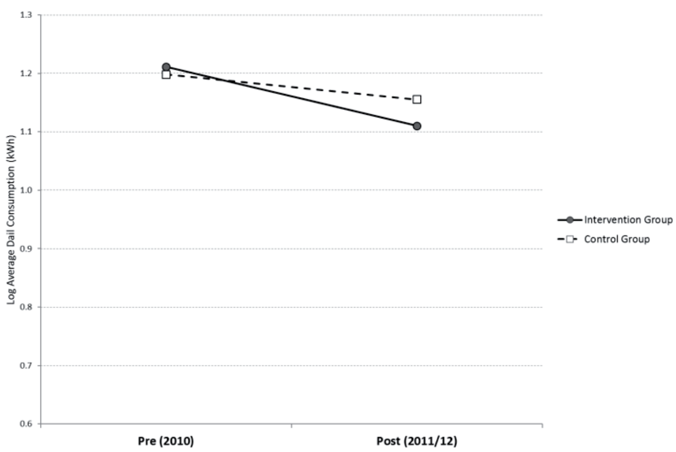

Figure 4. Change in Log ADC (kWh) by group (pre and post intervention).

mental and financial) and perceived behavioural control significantly contribute ($p<0.05$) to the predication of behavioural intentions. The subjective norm variable was not found to have a significant influence on intentions ($p>0.05$). Intentions to reduce energy use were found to be a significant predictor of changes in electricity use ($p<0.05$), while perceived behavioural control did not have a significant influence ($p<0.05$).

The adjusted R^2 for behavioural intentions was 0.25. This indicates that 25 % of the variance in intentions to reduce energy were explained by the model. According to Cohen (1988), this is a moderate effect ($f^2=0.34$). This variance explained in behavioural intentions is comparable to other studies that have tested the TPB (Armitage & Connor, 2001).

The variance explained in changes to electricity use was lower than behavioural intentions ($R^2=0.04$). This finding suggests that only a trivial amount of change in electricity use is explained by the intentions and perceived behavioural control variables ($f^2=0.04$). The higher predictability of the TPB variables on intentions than actual behaviours is consistent with previous studies applying this model (Armitage & Connor, 2001).

The strong fit between the TPB model and the study's data suggest that intentions completely mediate the influence of attitudes and perceived behavioural control on change in electricity use (i.e. actual behaviour). This finding suggests that although these constructs do not influence behaviour directly, they do so indirectly through their influence on intentions, which in turn has a direct effect on behaviour (refer Table 5).

MODERATING EFFECTS OF PROGRAM PARTICIPATION

A multi-group path analysis method was used to assess if program participation moderates the relationship between these variables. The TPB variables provided a good fit of behavioural intentions and behaviour (changes in electricity use) for both the intervention and control groups[2] ($\chi^2(6) = 15.2$, $p > .01$;

2. Data-model fit indices are calculated across both groups.

Table 4. Path Analysis Summary for TPB variables predicting intentions and behaviour.

Variable	B	SEB	β
Intentions			
PBC*	0.04	0.006	0.27
Subjective Norm	0.006	0.006	0.04
Attitudes (environment)*	0.03	0.006	0.20
Attitudes (financial)*	0.04	0.005	0.21
Intercept*	2.15	0.14	
Change in ADC (%)			
Intentions	-6.90	1.44	-0.22
PBC	0.35	0.20	0.07
Intercept	9.24	5.44	

Note: Intentions R2=0.25 (n=542, p<0.05). Change in ADC (%) R2=0.04 (n=542, p<0.05).
**p<0.05*

Table 5. Direct and indirect effects of TPB variables on intentions and behaviour.

	Intentions		Change in ADC (%)		
	Total Effect	Direct Effect	Total Effect	Direct Effect	Indirect Effect
Attitudes (environment)	0.21	0.21	-0.05	na	-0.05
Attitudes (financial)*	0.21	0.21	-0.05	na	-0.05
Subjective Norm	ns	ns	ns	na	-0.01
PBC	0.27	0.27	ns	ns	-0.06
Intention	na	na	-0.22	-0.22	0.00

Note: Figures are β coefficients; ns=not signficant; na=not applicable.

CFI = .97; NFI = .96; RMSEA = .05). A comparison of regression weights suggests that the influence of each variable is invariant across both the control and intervention groups.

This multi-group analysis suggests that participation in the program does not affect the direction and/or strength of the relationship between the model's independent and response variables. Therefore, there is no evidence that program participation moderates the TPB model in this study.

The only significant difference between the two groups related to the intercept for behavioural intentions, which suggests that average intentions for the intervention group are higher than the control group, even after controlling for attitudes, subjective norm and perceived behavioural control. This finding suggests that exogenous factors to the TPB are influencing the intervention group's predisposition to have stronger intentions to reduce energy use. In contrast, the intercepts for changes in energy use are invariant across both groups. This suggests that average changes in energy use are similar for both groups when controlling for the influence of behavioural intentions.

Discussion

This study sought to examine how energy efficiency programs influence participant behaviour. This was done by applying the TPB to test how program participation influences the relationship between intentions, behaviour and their determinants. This is the first study that has assessed if energy efficiency programs strengthen the influence of such relationships using a quasi-experimental research design.

The results show that 5.8 % of the electricity use reductions observed in the intervention group can be attributed to participation in the CVSC program. This finding suggests that the program was successful in encouraging participants to change their energy use behaviour. The influence of this program is consistent with similar feedback programs, where a decrease of between 5 % and 12 % has usually been observed (Fischer, 2008). It is important to recognise that this result refers to the main impact of the program. Participant outcomes may have varied depending on participant characteristics and adoption of the program's additional packages: retrofit rebate; household solar electricity; solar hot water; and in home energy displays. Although measuring such distributional program effects were beyond the scope of the current study, such analysis would provide a more detailed assessment of the program's impact on participant behaviour.

The study found that the TPB is a plausible model to explain household energy use intentions and behaviour. In particular, the model explained a moderate level of variance in participant intentions to reduce energy use (24 %), but only a relatively small amount of variance in actual electricity use consumption (4 %). The higher predictability of the TPB variables on intentions than actual behaviours is consistent with previous studies applying this model (Armitage & Connor, 2001). It is proposed that the low predictability of changes in electricity use may be because of perceived behavioural control being a poor proxy for actual control for energy consumption. Participants in both the intervention and control groups generally reported high levels of perceived controllability concerning their ability to reduce energy use. Such a discrepancy may be because of cogni-

Table 6. Moderation analysis: test of group differences.

	Intervention		Control		
Variable	B	SEB	B	SEB	z-score
Intentions					
PBC	0.03	0.006	0.04	0.008	0.44
Subjective Norm	0.01	0.007	0.00	0.009	-0.88
Attitudes (environment)	0.03	0.007	0.03	0.009	0.72
Attitudes (financial)	0.02	0.006	0.04	0.008	1.65
Intercept	2.59	0.16	1.78	0.20	-3.16*
Change in ADC (%)					
Intentions	-7.98	2.86	-3.54	1.61	1.35
PBC	0.68	0.33	0.01	0.25	-1.64
Intercept	4.64	10.89	5.82	5.99	0.10

tive difficulties in considering peripheral internal and external factors (barriers/enablers) likely to influence such behaviour. Such internal factors may include bounded rationality, where rational decision-making is limited by information constraints and cognitive biases (Simon, 1991). Participants may also have had difficulty predicting the influence of external factors such as climatic effects, appliance replacements, changes to household structure, technology advances and energy price changes. Developments in behavioural economics concerning biases in decision-making may provide a useful theoretical framework to explain discrepancies between perceived and actual control over energy consumption (Kahneman, 2011; Thaler, 2009).

The analysis found that intentions to reduce energy use were mainly influenced by attitudes towards the environmental and financial benefits of reducing consumption and perceived control over such behaviour. Subjective norms did not have a significant influence on behaviour, which is consistent with previous studies that have applied the TPB model to energy use (Abrahamse & Steg, 2011; Midden & Ritsema, 1986). This finding suggests that social pressure does not appear to be an important determinant of energy use intentions in the context of other attitudes and beliefs. Nevertheless, some programs using persuasive appeals to evoke social norms have experienced mixed success (Allcott, 2011; Schultz et al., 2007; White & Simpson, 2013). Further research on the influence of social norms on energy conservation is therefore encouraged.

Although the TPB model only explained a relatively small amount of variance in electricity use changes, behavioural intentions were found to have a significant influence. This supports a fundamental assumption of the TPB, that intentions are close antecedents of overt behaviour. This is also supported by the finding that the average changes in energy use was similar for both groups when controlling for levels of intentions to reduce energy use. The analysis also found that perceived behavioural control did not significantly influence actual behaviour, which again could be explained by a discrepancy between perceived and actual controllability. The strong fit between the TPB model and the data collected for this study suggest that attitudes and perceived behavioural control influence changes in electricity use indirectly through their influence on behavioural intentions. This finding suggests that programs that successfully influence participant attitudes towards energy conservation and address barriers to adopting such behaviours are likely to have a positive effect on reducing energy use. Therefore it is recommended that future research be undertaken into the determinants of attitudes and perceived barriers towards reducing energy use. Developments in this area are expected to help policy makers and program administrators to design and implement more effective energy efficiency programs.

The analysis found that program participation did not strengthen (i.e. moderate) the influence of attitudes or beliefs on intentions to reduce energy use or actual behavioural changes. A possible reason for this finding is that changes in intentions and behaviour may be driven by changes in attitudes and beliefs towards energy use rather than by program participation strengthening the relationship between these constructs. For example, program participation may foster more positive attitudes towards energy conservation rather than strengthen the influence of pre-program attitudes on intentions and behaviour. To test this proposition, it is recommended that future research investigates the longitudinal influence of energy efficiency programs on changes to participant attitudes, beliefs and intentions, and in turn, the effect of such changes on energy use behaviour.

This study was conducted for a single program in Central Victoria, Australia and cannot necessarily be generalised to other regions or programs. To test the generalisability of the results from this study, it is recommended that the study's findings are tested in other regions and for different types of energy efficiency programs.

Besides examining the average impacts of energy efficiency programs interventions, energy efficiency policy makers can benefit from understanding how programs have influenced participant behaviour. This study has demonstrated that the TPB model provides a plausible model for understanding and measuring the dynamics of household energy use. Further research into the influence of programs on changing the determinants of intentions and behaviour will provide greater insight into participant behaviour in response to such initiatives. Such knowledge will help to ensure better policy decisions aimed at achieving energy security and lowering carbon pollution.

References

Abrahamse, W., & Steg, L. (2009). How do socio-demographic and psychological factors relate to households' direct and indirect energy use and savings? Journal of Economic Psychology, 30, 711–720.

Abrahamse, W., Steg, L., Vlek, C., & Rothengatter, T. (2005). A review of intervention studies aimed at household energy conservation. Journal of Environmental Psychology, 25(3), 273–291.

Abrahamse, W., & Steg, L. (2011). Factors related to household energy use and intention to reduce it: The role of psychological and socio-demographic variables. Human Ecology Review, 18(1), 30–40.

Allcott, H. (2011). Social norms and energy conservation. Journal of Public Economics, 95(9), 1082–1095.

Ajzen, I. (1991). The theory of planned behavior. Organizational Behavior and Human Decision Processes, 50(2), 179–211.

Ajzen, I. (2005). Attitudes, Personality and Behaviour. 2nd edition. Berkshire: Open University Press.

Ajzen, I., & Fishbein, M. (2005). The influence of attitudes on behavior. In D. Albarracín, B. T. Johnson & M. P. Zanna (Eds.), The handbook of attitudes (pp. 173–221). Mahwah, NJ: Erlbaum.

Allcott, H., & Greenstone, M. (2012). Is there an energy efficiency gap? (No. w17766). National Bureau of Economic Research.

Allison, P. (2001). Missing data (quantitative applications in the social sciences). California: Sage Publications.

Armitage, C. J., & Conner, M. (2001). Efficacy of the theory of planned behaviour: A meta-analytic review. British journal of social psychology, 40(4), 471–499.

Barr, S., Gilg, A. W., & Ford, N. J. (2001). A conceptual framework for understanding and analysing attitudes towards household-waste management. Environment and Planning A, 33(11), 2025–2048.

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). New Jersey: Lawrence Erlbaum.

Cook, T. D., Campbell, D. T., & Day, A. (1979). Quasi-experimentation: design & analysis issues for field settings (pp. 19-21). Boston: Houghton Mifflin.

Corraliza, J. A., & Berenguer, J. (2000). Environmental values, beliefs, and actions: a situational approach. Environment and Behavior, 32(6), 832–848.

Department of Resources Energy and Tourism (2012). Energy white paper 2012: Australia's energy transformation. Canberra: Commonwealth of Australia.

Dietz, T. (2010). Narrowing the US energy efficiency gap. Proceedings of the National Academy of Sciences, 107(37), 16007–16008.

Dillman, D. A. (2007). Mail and internet surveys: the tailored design method. Hoboken: John Wiley & Sons.

Dunlap, R. E., Van Liere, K. D., Mertig, A. G., & Jones, R. E. (2002). New trends in measuring environmental attitudes: measuring endorsement of the new ecological paradigm: a revised NEP scale. Journal of Social Issues, 56(3), 425–442.

Engel, J. F., Blackwell, R. D., & Miniard, P. W. (1990). Consumer behaviour (6th ed.). Chicago: Dryden Press.

Francis, J. J., et al. (2004). Constructing questionnaires based on the theory of planned behaviour: a manual for health services researchers.

Garnaut, R. (2008). The Garnaut climate change review. Melbourne: Cambridge University Press,

Geller, H. (2002). Energy revolution: policies for a sustainable future. Washington D.C.: Island Press.

Fischer, C. (2008). Feedback on household electricity consumption: a tool for saving energy?. Energy Efficiency, 1 (1), 79–104.

Harland, P., Staats, H., & Wilke, H. A. (1999). Explaining proenvironmental intention and behavior by personal norms and the theory of planned behavior. Journal of Applied Social Psychology, 29(12), 2505–2528.

Howard, J. A., & Sheth, J. N. (1969). The theory of buyer behavior. New York: John Wiley & Sons.

International Energy Agency. (2005) Energy policies of IEA countries: Australia 2005 Review. Paris: IEA.

Jaffe, A. B., & Stavins, R. N. (1994). The energy-efficiency gap: what does it mean?. Energy Policy, 22(10), 804–810.

Jöreskog, K.G. (1990). New developments in LISREL: analysis of ordinal variables using polychoric correlations and weighted least squares. Quality and Quantity, 24, 387–404.

Kahneman, D. (2011). Thinking, fast and slow. New York: Farrar, Straus and Giroux.

Lindenberg, S., & Steg, L. (2007). Normative, gain and hedonic goal frames guiding environmental behavior. Journal of Social Issues, 63, 117–137.

Little, R.J.A. and Rubin, D.B. (2002). Statistical Analysis with Missing Data, 2nd edition, New York: John Wiley.

Lynne, G. D., Franklin Casey, C., Hodges, A., & Rahmani, M. (1995). Conservation technology adoption decisions and the theory of planned behavior. Journal of Economic Psychology, 16(4), 581–598.

Macintosh, A., & Wilkinson, D. (2011). Searching for Public Benefits in Solar Subsidies: A case study on the Australian government's residential photovoltaic rebate program. Energy Policy, 39(6), 3199–3209.

Midden, C. J., & Ritsema, B. S. (1986). The meaning of normative processes for energy conservation. Journal of Economic Psychology, 4, 37–55.

Olli, E., Grendstad, G., & Wollebaek, D. (2001). Correlates of environmental behaviors bringing back social context. Environment and Behavior, 33(2), 181–208.

Peter, J. P., & Olson, J. C. (2004). Consumer behavior and marketing strategy. New York: McGraw-Hill.

Schultz, P. W., & Oskamp, S. (1996). Effort as a moderator of the attitude-behavior relationship: General environmental concern and recycling. Social Psychology Quarterly, 375–383.

Schultz, P. W., Nolan, J. M., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2007). The constructive, destructive, and reconstructive power of social norms. Psychological Science, 18(5), 429–434.

Schwartz, S. H. (1992). Universals in the context and structure of values: Theoretical advances and empirical tests in 20 countries. Advances in Experimental Social Psychology, 25, 1–65.

Simon, H. A. (1991). Bounded rationality and organizational learning. Organization science, 2(1), 125–134.

Steel, B. S. (1996). Thinking globally and acting locally?: environmental attitudes, behaviour and activism. Journal of Environmental Management, 47(1), 27–36.

Steg, L., Dreijerink, L., & Abrahamse, W. (2006). Why are energy policies acceptable and effective?. Environment and Behavior, 38(1), 92–111.

Stern, P. C. (1992). What psychology knows about energy conservation. American Psychologist; American Psychologist, 47(10), 1224.

Stern, P. C. (2000). Toward a coherent theory of environmentally significant behavior. Journal of Social Issues, 56, 407–424.

Stern, P. C. (2002). New environmental theories: toward a coherent theory of environmentally significant behavior. Journal of social issues, 56(3), 407–424.

Stern, P. C., Dietz, T., & Guagnano, G. A. (1995). The new ecological paradigm in social-psychological context. Environment and Behavior, 27(6), 723–743.

Stern, P. C., Dietz, T., Abel, R., Guagnano, G. A., & Kalof, L. (1999). A value-belief-norm theory of support for social movements: The case of environmentalism. Human Ecology Review, 6, 81–97.

Stuart, E. A. (2010). Matching methods for causal inference: A review and a look forward. Statistical science: a review. Journal of the Institute of Mathematical Statistics, 25(1), 1.

Thaler, R. H., & Sunstein, C. R. (2008). Nudge: Improving decisions about health, wealth, and happiness. New Haven, CT: Yale University Press.

Trochim, W. (2001). The research methods knowledge base (2nd ed.). Cincinnati, OH: Atomic Dog Publishing.

Vining, J., & Ebreo, A. (1992). Predicting recycling behavior from global and specific environmental attitudes and changes in recycling opportunities. Journal of Applied Social Psychology, 22(20), 1580–1607.

White, K., & Simpson, B. (2013). When do (and don't) normative appeals influence sustainable consumer behaviors? Journal of Marketing, 77 (2), 78–95.

Wilson, C., & Dowlatabadi, H. (2007). Models of decision making and residential energy use. Annual Review of Environment and Resources, 32, 169–203.

Acknowledgements

We are also indebted to the support and guidance provided by fellow researchers at the University of Ballarat, in particular, Bob Bateman, Dr. Patrice Braun, Prof. Julian Lowe, Sasha Ivkovic, Emily Richards and all field staff who assisted with this study. We thank the Department of the Climate Change and Energy Efficiency, Sustainability Victoria, the Sustainability Fund and the CVSC Consortium for their support in commissioning this study. We also share our gratitude to the CVSC program's administrators Sustainable Regional Australia and Powercor for helping with the study's data collection activities.